

1 **Interactive comment on “Effect of Sampling Variation on**
2 **Error of Rainfall Variables Measured by Optical**
3 **Disdrometer by X. C. LIU et al**

4
5 **1 Summary**

6 This manuscript presents a simulation study of the sampling effects on various quantities
7 related to rainfall measured by optical disdrometers. The arrival of raindrops is supposed to be
8 a Poisson process, and its parameter is related to climatological/characteristic DSD measured
9 for different types of rain events in China. The sampling effect due to the size of the sample,
10 the size of the sampling area and the rain rate are then investigated for different
11 moments/descriptors of the DSD and for different optical disdrometers, as well as the
12 sampling uncertainty in fall speed estimates. These errors appear to be limited for the
13 considered quantities.

14 **2 Recommendation**

15 The idea motivating this study is interesting and relevant as the DSD is more and more
16 commonly measured and used, in particular for radar rain rate estimation. However, the
17 approach employed and the results presented in this manuscript are not well explained/
18 introduced. So the reader is a bit confused on what exactly is investigated and how. In
19 addition, there are major issues in my opinion (e.g., reflectivity values in the order of 100 dBZ)
20 which question the validity/reliability of the results and conclusions. Given the large amount
21 of work required to address these issues and to reshape the manuscript, I recommend to reject
22 this manuscript. In order to help the authors improving their manuscript, I provide below a list
23 of comments/suggestions about issues to be addressed.

24 **Response:** Thanks for your comments of our work. We have modified our manuscript and
25 corrected issues to make this manuscript more publishable. The details are as follows.

26
27 **3 General Comments**

28 1. The English is not good enough for publication in an international journal like AMT.
29 Although I am not a native speaker, I found many strange or misleading sentences in the text

1 that must be corrected. For example, the use of the terms “number”, “concentration”, “size”
2 and “density” throughout the text is confusing/misleading. Just in the abstract, what exactly is
3 “water concentration” on 1.9, “number density” on 1.11, “margin probability” on 1.12,
4 “sampling size” on 1.14? I am aware that this is not easy for non-native speakers, but this must
5 be done.

6 **Response:** Thanks for your comments of our work. We have modified the above errors in our
7 revised manuscript according to your suggestions. “water concentration” was replaced by
8 “water content”, “number density” was replaced by “number concentration”, “margin
9 probability” is defined as the probability of drops partially seen by the measurement beam,
10 was replaced by “probability of margin raindrops”, “sampling size” is defined as the size of
11 sampling area. Besides, we have invited professional English native speaker to check for the
12 spelling and grammatical errors to make this manuscript legible.

13 2. Section 2 is not clear, and the approach to simulate raindrops arrival time and DSDs should
14 be better explained (and the required assumptions and associated limitations should be
15 mentioned). This is a key issue as all the results and conclusions depend on the quality of the
16 simulated DSDs.

17 **Response:** Thanks for your comments of our work. We have added more explanation about
18 the simulation and approach.

19 3. Related to the previous item, the fact that the authors provide radar reflectivity values in the
20 order of 100 dBZ is a big concern. First such values are not realistic (reflectivity in rain is
21 around 60 dBZ max, maybe a bit more in exceptional cases, but I have never seen measured
22 values around 100 dBZ). Second, this raises the question of the maximum (equivolumetric)
23 raindrop diameter simulated, about which I could not find any info in the text. So I am
24 wondering if the authors have rigorously check their simulations...

25 **Response:** We are sorry for the obvious error of reflectivity values; the reason is that the
26 radar reflectivity values were calculated by logarithm base e instead of base 10 mistakenly, it
27 has be corrected in the revised manuscript (The maximum reflectivity is 63.44 dBZ when
28 rainrate is 100 mm/h). Second, the interval of equivolumetric raindrop diameter simulated in
29 this manuscript is 0.05mm ~ 6.0 mm.

30 4. The goal is to quantify the sampling effect in DSD measurements from optical
31 disdrometers. The DSDs are however simulated from Gamma DSD fitted to measured DSDs.

1 The quality of the fit of the Gamma DSD model on the measured DSD spectra should be
2 discussed or at least mentioned.

3 **Response:** Your suggestions are reasonable, however, this paper mainly discuss the sampling
4 effect on DSD measurement based on different types of rainfall, the parameters of DSDs in
5 Table 1 are from several studies about DSDs measurements and analysis, this manuscript
6 didn't fit the measured DSDs but summarized their conclusions. The different DSDs are only
7 a reference for simulation; we don't think that the assessment of quality of the fit could help
8 to understanding the simulation in this manuscript.

9 **Specific comments**

10 1. P.8896, 1.26: a better reference than Battaglia et al. (2010) presenting the Parsivel is
11 Löffler-Mang and Joss (2000).

12 **Response:** Thank you for your suggestions, we have modified it.

13 2. P.8897, 1.8-9: this radar is known as MRR. The POSS could also be mentioned (Sheppard,
14 1990).

15 **Response:** Thank you for your suggestions, we have modified it.

16 3. P.8898, 1.9-11: The sampling uncertainty associated with Parsivel has been experimentally
17 investigated and quantified Jaffrain and Berne (2011). This reference should be in this
18 manuscript.

19 **Response:** Thank you for your suggestions, we have added this reference.

20 4. P.8899, Eq.1 and 1.2-3: $N(D)$ given in Eq.1 is not the concentration of drops per unit
21 volume, $N(D)dD$ is (the number of drops with diameter between D and $D + dD$ per unit
22 volume). In addition, N_0 in Eq.1 is not the total concentration number (its units depend on μ).
23 Moreover, the units should be provided for quantities/variables used in all the equations
24 throughout the paper.

25 **Response:** Thank you for your comment, we have corrected them.

26 5. P.8899, 1.23-24: there are also studies in the literature that do not support the Poisson model
27 for raindrops (see the work by Jameson and co-authors for example).

1 **Response:** Indeed, there are also studies that do not support the Poisson model and many non-
2 homogeneous models for raindrops, but this paper are restricted to the application of
3 homogeneous Poisson model.

4 6. P.8900, Eq.4: λ here is confusing with λ in Eq.1. It should be changed.

5 **Response:** Thank you for your comment; we have replaced λ by γ in Eq.4.

6 7. P.8900, Eq.7: a reference should be given for this model, as it does not seem to be
7 commonly used (maybe I am wrong...).

8 **Response:** Eq.7 is come from a book published in china, but due to the unphysical
9 discontinuity at $D=0.1$ and 1 mm, we used the velocity model of raindrops
10 $v(D) = 3.78D^{0.67}$ by Atlas and Ulbrich in the revised manuscript.

11 8. P.8901-8902, Eq.11-14: over what range of diameter are these sums computed?

12 **Response:** the range of diameter simulated is: $0.05\text{mm} \sim 6\text{mm}$.

13 9. P.8903, l.2: if it is true, a reference showing that Parsivel is the "the most widely used
14 instrument" should be given.

15 **Response:** we are sorry for the inaccurate expressions, "the most widely used instrument"
16 was replaced by "one of the most widely used instruments".

17 10. P.8903, l.5: I think that this sampling area of $180*27$ mm² corresponds to the PMTech
18 instrument, and I think it is $180*30$ mm² for the OTT Parsivel.

19 **Response:** the sampling area of $180*27$ mm² is from the Battaglia et al. (2010), in which the
20 OTT PARSIVEL was analyzed.

21 11. P.8903, l.19: why 10 runs and not 5 or 100?

22 **Response:** We have tested the simulaiton with different runs, because one single simulation
23 shows obvious randomness, the randomness of single simulation can be eliminated by many
24 runs of simulation; while too less runs are esily influenced by randomness, too more runs
25 mean a waste of time and of no help to the simulation results, therefore a compromise runs
26 (10 runs) for each simulation are used.

27 12. P.8903, l.20: what is the definition of this relative error?

1 **Response:** the relative error is defined as $\Delta = \frac{VAR_{retrieved} - VAR_{simulated}}{VAR_{simulated}}$. where $VAR_{simulated}$ and

2 $VAR_{retrieved}$ denote the simulated variables and retrieved variables.

3 13. P.8904, Section 3.2: what is the sample size (in number of drops) or duration considered
4 in this analysis?

5 **Response:** the detailed number of drops simulated can be found in Table 3. and Table 4.

6 14. P.8906, 1.26-27: as the drops partially crossing the beam are better detected (and removed)
7 by Parsivel thanks to the 2 photodiodes, I am surprised that the error is positive in Nd in Table
8 6 (+0.14%), indicating an overestimation of the total number of drops. I would expect an
9 underestimation if the "margin fallers" are removed...

10 **Response:** according to the retrieval rational of OTT PARSIVEL, the raindrops partially
11 crossing the beam were removed by 2 photodiodes, but at the same while the sampling area
12 becomes $180mm \times (27mm - 2D_{eq}^{par})$, hence the relative error might be positive. After many
13 simulations, the probability of negative relative error is greater than that of positive relative
14 error. It has been corrected in the revised manuscript.

15 15. P.8906, Section 3.4: it would be very interesting to investigate the probability to have
16 multiple drops at the same time as a function of the sampling area. This is the main reason to
17 keep it relatively small (except for the 2DVD for which the 2 perpendicular cameras help
18 solving this issue).

19 **Response:** We mainly focus on the sampling area and DSDs in this paper, the probability of
20 multiple drops at the same time could be very interesting, but 2DVD can detect multiple drops
21 at the same time, other disdrometers can not detect, this error source of disdrometers will be
22 discussed in another paper.

23 16. References: the article by Battaglia et al. (2010) was published in 2010 not in 2009.

24 **Response:** Thank you for your comment, we have corrected it.

25 17. Table 1: the parameter μ of the Gamma DSD model should be given as well. In addition,
26 the units are erroneous for N_0 .

27 **Response:** Thank you for your comment, we have added the parameter μ and corrected the
28 unit of N_0 .

1 18. Tables 2-3-4: the values of reflectivity reported in these tables are way too large.

2 **Response:** We are sorry for the obvious error of reflectivity values; the reason is that the
3 radar reflectivity values were calculated by logarithm base e instead of base 10 mistakenly, it
4 has be corrected in the revised manuscript.

5 19. Figure 1: the notation R... in the legend of the figure is confusing as R is supposed to be
6 constant (as indicated in the caption). Maybe the term "DSD" should be used?

7 **Response:** Thank you for your advice, we have corrected it.

8 20. Figure 2: I am surprised that the higher order moments of the DSD (like Z) are less
9 sensitive to the sample size. A few big drops less (or more) due to sampling effects have a
10 larger influence on the higher order moment values. The authors should comment on this.

11 **Response:** the unit of radar reflectivity Z in this manuscript is dBZ, the larger influence of
12 sampling effects on the higher order moment values is distorted by the logarithmic
13 transformation. According to the advices of referee, we analyzed the Z with the linear units
14 ($\text{mm}^6 \text{ m}^{-3}$) and computed the relative error in the revised manuscript, where the sampling
15 effects showed the largest influence on Z error.

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